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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with the operation and maintenance of a chemical precipitation softening system. Included are objectives, instructor guides, student handouts and transparency masters. This is the third level of a three module series. This module considers the application of process theory and laboratory data for optimal process control, troubleshooting process and design problems and sludge handling and disposal alternatives. (Author/RH)

ADVANCED CHEMICAL PRECIPITATION SOFTENING

Training Module 2.217.4.77

Prepared for the

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by

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September, 1977

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INSTRUCTOR GUIDE

for

Training Module II4AGWS

Module No:	Module Title:
I-I4AGWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
12 hours	Topic:
	Summary

Objectives: Upon completion of this module, the participant will be able to:
1. Describe the theory of chemical precipitation softening.
2. Determine the optimal operation of a chemical precipitation softener.
3. Describe sludge disposal alternatives.

Instructional Aids:
1. Handout
2. Transparencies #1-#13

Instructional Approach:
Discussion and Class Problems

References:

1. Manual of Water Utility Operations, Texas Water Utility Assoc.
2. Water Supply & Treatment, National Lime Association.
3. Mathematical Approach to Ionic Equilibrium, Butler.

Class Assignments:

1. The participant will read Handout.
2. The participant will complete Problems #1.

Module No:	Topic:
II4AGWS	Summary

Instructor Notes:	Instructor Outline:
1. Distribute Handout	1. Discuss the theory, optimal operation and sludge disposal alternatives for chemical precipitation softening.
2. Present Transparencies	2. Give evaluation of 30 questions.

Module No:	Module Title:
II4AGWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
1 hour	Introduction

Objectives: Upon completion of this topic, the participant will be able to:
1. Describe chemical precipitation softener operation.
2. Describe chemical precipitation softener maintenance.
3. Describe chemical precipitation softener analytical control.

Instructional Aids:
1. Handout-Introduction
2. Transparency #1 - Two Stage Softening
3. Transparency #2 - Split Treatment Softening
4. Transparency #3 - Single Stage Softening
5. Transparency #4 - Laboratory Control

Instructional Approach:

Discussion

References:

1. Manual of Water Utility Operations, Texas Water Utility Association.
2. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Introduction.

Module No:	Topic:
II-AGWS	Introduction

Instructor Notes:	Instructor Outline:
1. Present Transparency #1	1. Review the operation of a two stage softening plant.
2. Present Transparency #2	2. Review the operation of a split treatment softening plant.
3. Present Transparency #3	3. Review the operation of a single stage softening plant.
4. Present Transparency #4	4. Review the laboratory control necessary for the operation of a chemical precipitation softening plant.

Module No:	Module Title:
II4GWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
3 hours	Topic: Theory of Chemical Precipitation Softening

Objectives: Upon completion of this topic, the participant will be able to:

1. Describe the theory of chemical precipitation softening.
2. Apply the theory of chemical precipitation softening.
3. Describe the theory of recarbonation.
4. Apply the theory of recarbonation to process operation.

Instructional Aids:

1. Handout-Theory of Chemical Precipitation Softening.
2. Transparency #5-Equilibrium Equation
3. Transparency #6-Solubility Product
4. Transparency #7-Carbon Dioxide System

Instructional Approach:

Discussion and class problem

References:

1. Manual of Water Utility Operations, Texas Water Utility Association.
2. Water Supply & Treatment, National Lime Association.
3. Mathematical Approach to Ionic Equilibrium, Butler.

Class Assignments:

1. The participant will read Handout-Theory of Chemical Precipitation Softening.
2. The participant will complete Problem #1 on chemical precipitation.

Module No:	Topic:
II4GWS	Theory of Chemical Precipitation Softening

Instructor Notes:	Instructor Outline:
1. Present Transparency #5	1. Discuss the equilibrium equation and its general applications to water treatment problems.
2. Present Transparency #6	2. Discuss the application of the equilibrium equation to the precipitation of ions in water. Discuss in detail how the equilibrium of a precipitation reaction can be shifted increase or decrease the components of the reaction.
3. Present Transparency #7	3. Discuss the application of the equilibrium equation to the carbon dioxide system. Discuss in detail the various components of the system and how pH affects the chemical composition of the water.
4. Present Class Problem #1. Work with class participation.	4. 1. HCO_3^- 2. $[Mg] = 10/100,000 = 1 \times 10^{-4}$ $\therefore [OH] = \left[\frac{1.2 \times 10^{-11}}{1 \times 10^{-4}}\right]^{\frac{1}{2}} = 3.5 \times 10^{-4}$ $pOH = 3.46$ $pH = 14 - 3.46 = 10.54$ 3. $[CO_3] = \frac{40}{60,000} = 6.67 \times 10^{-4}$ moles/liter $\therefore [Ca] = \frac{8.7 \times 10^{-9}}{6.67 \times 10^{-4}} = 1.3 \times 10^{-4}$ moles/lt $[Ca] = 52$ mg/l as Ca^- or $[Ca] = 13$ mg/l as $CaCO_3$

Module No: _	Topic:
II4GWS	Theory of Chemical Precipitation Softening

Instructor Notes:	Instructor Outline:
	4. $[HCO_3] = \frac{200}{41,000} = 4.88 \times 10^{-3}$ $\therefore [CO_2] = \frac{(4.88 \times 10^{-3})(16)}{84} = 9.29 \times 10^{-4}$ $\therefore [CO_2] = (9.29 \times 10^{-4})(44,000) = 40$ mg/l

Module No:	Module Title:
II4GWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
4 hours	Topic: Interpretation and Application of Laboratory Data

Objectives:

Upon completion of this topic, the participant will be able to:

1. Interpret laboratory data to check compliance with design standards.
2. Interpret laboratory data to evaluate existing softeners.
3. Interpret laboratory data to determine optimal operation.

Instructional Aids:

1. Handout - Interpretation of Laboratory Data.
2. Transparency #8-Lime Analysis
3. Transparency #9-Soda Ash Analysis
4. Transparency #10-Optimal Operation

Instructional Approach:

Discussion

References:

1. Manual of Water Utility Operations, Texas Water Utility Association.
2. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Interpretation of Laboratory Data.

Module No:	Topic:
II4GWS	Interpretation and Application of Laboratory Data

Instructor Notes:	Instructor Outline:
1. Present Transparency #8	1. Discuss the procedure for determining the quality of lime. Discuss this test in relation to normal standard for % CaO.
2. Present Transparency #9	2. Discuss the procedure for determining the quality of Soda Ash. Discuss this test in relation to normal standard for % Na_2CO_3.
3. Present Transparency #10	3. Discuss how laboratory data can provide the optimal operation for a plant.

Module No:	Module Title:
SI4GWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time: 2 hours	Topic: Sludge Disposal

Objectives: Upon completion of this topic, the participant will be able to:

1. Describe various sludge disposal alternatives.
2. Describe advantages and disadvantages for sludge disposal alternatives.
3. Describe basic operation of sludge disposal alternatives.

Instructional Aids:

1. Handout-Sludge Disposal
2. Transparency #11 - Softening Sludge Characteristics
3. Transparency #12 - Solids Disposal

Instructional Approach:

Discussion

References:

1. Manual of Water Utility Operations, Texas Water Utility Association.
2. Water Supply & Treatment, National Lime Association.
3. Mathematical Approach to Ionic Equilibrium, Butler.

Class Assignments:

1. The participant will read Handout-Sludge disposal

Module No:	Topic:
II4GWS	Sludge Disposal

Instructor Notes:	Instructor Outline:
1. Present Transparency #11	1. Discuss the characteristics of chemical precipitation softening sludge. Discuss in detail those properties that make it easy and difficult to dewater.
2. Present Transparency #12	2. Discuss each step in the solids disposal system. Discuss places where each step may be needed and where it may not be needed. Give general performance of each step and what is trying to be accomplished in each.

Module No:	Module Title:
II4GWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
1 hour	Topic:
	Special Applications

Objectives: Upon completion of this topic, the participant will be able to:

1. Describe hot lime softening.
2. Describe basic operation of hot lime softening.

Instructional Aids:

1. Handout-Special Applications
2. Transparency #13 - Hot Lime Softening

Instructional Approach:

Discussion

References:

1. Manual of Water Utility Operations, Texas Water Utility Association.
2. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Special Applications.

Module No:	Topic:
II4GWS	Special Applications

Instructor Notes:	Instructor Outline:
1. Present Transparency #13	1. Discuss the equipment used and the operation of a hot lime softening plant. Discuss in detail the difference between the hot lime and conventional lime softener. Relate the theory of softening to explain the differences between the two types of softening.

Module No:	Module Title:
II4GWS	Advanced Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
1 hour	Topic:
	Evaluation

Objectives:

The participant should be able to answer correctly 250 of the 30 questions asked.

Instructional Aids:

None

Instructional Approach:

Examination

References:

None

Class Assignments:

None

Module No:	Topic:
II4GWS	Evaluation

Instructor Notes:	Instructor Outline:
1. Distribute exam. Each participant is to complete the exam independently and with no books or notes. Collect after 1 hour.	

TRANSPARENCIES

for

Training Module II4AGWS

TWO STAGE SOFTENING

1. FIRST STAGE
   A) PH SHOULD BE ADJUSTED TO ABOVE 11.0 WITH LIME TO OBTAIN MAGNESIUM REMOVAL. THIS PH CAN BE REDUCED SOMEWHAT IF NOT TOTAL MAGNESIUM REMOVAL IS REQUIRED.
2. SECOND STAGE
   A) PH OF THE SECOND STAGE SHOULD BE APPROXIMATELY 10 TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   B) IF SODA ASH IS USED IT SHOULD BE ADDED JUST PRIOR TO THE SECOND STAGE TO HELP REDUCE THE PH.
   C) RECARBONATION WITH CARBON DIOXIDE IS USUALLY REQUIRED TO LOWER THE PH TO THE OPTIMUM LEVEL.
   D) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL PH IS DEPENDENT ON THE WATER, CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL PH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

SPLIT TREATMENT SOFTENING

1. FIRST STAGE
   - A) pH SHOULD BE ADJUSTED TO ABOVE 11.0 WITH LIME TO OBTAIN MAGNESIUM REMOVAL. THIS pH CAN BE REDUCED SOMEWHAT TO OBTAIN THE DESIRED TOTAL MAGNESIUM REMOVAL.
2. SECOND STAGE
   - A) pH OF THE SECOND STAGE SHOULD BE APPROXIMATELY 10 TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   - B) IF SODA ASH IS USED IT SHOULD BE ADDED JUST PRIOR TO THE SECOND STAGE TO HELP REDUCE THE pH.
   - C) GENERALLY THE CARBON DIOXIDE AND BICARBONATE IN THE SPLIT FLOW IS ADEQUATE TO LOWER THE pH IN THE SECOND STAGE TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   - D) IF pH DROPS BELOW 10.0 ADD ADDITIONAL LIME TO SECOND STAGE TO OBTAIN THE DESIRED CALCIUM REDUCTION.
   - E) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL pH IS DEPENDENT ON THE WATER CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL pH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

SINGLE STAGE SOFTENING

1. SINGLE STAGE

A) pH SHOULD BE ABOVE 10 TO OBTAIN ACCEPTABLE PERFORMANCE OF THE SOFTENER. IF MAGNESIUM REMOVAL IS DESIRED, THE pH SHOULD BE ABOVE 11.0. THE OPTIMUM OPERATION, THAT OPERATION RESULTING IN THE LEAST HARDNESS, WILL BE DIFFERENT FOR EACH PLANT, RESULTING IN SOME EXPERIMENTATION TO DETERMINE WHAT pH IS OPTIMAL.

B) ALL CHEMICAL FEEDS ARE ADDED JUST AT THE HEAD OF THE UNIT.

C) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL pH IS DEPENDENT ON THE WATER, CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL pH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

LABORATORY CONTROL

A. PHYSICAL
   1. TEMPERATURE
   2. TURBIDITY

B. CHEMICAL
   1. ALKALINITY
   2. TOTAL AND CALCIUM HARDNESS
   3. TOTAL DISSOLVED SOLIDS
   4. pH
   5. SOLIDS CONCENTRATION (UPFLOW UNITS ONLY)
   6. "CATALYST" ANALYSIS ("SPIRACTOR" ONLY)

EQUILIBRIUM EQUATION

$A_NB_M \rightleftharpoons NA^+ + MB$

EQUILIBRIUM EXPRESSION

$(A)^N(B)^M/(A_NB_M) = K_{EQ}$

SOLUBILITY PRODUCT

$A_NB_M \rightleftharpoons NA^+ + MB^-$

EQUILBRIUM EXPRESSION

$(A)^N(B)^M/(A_NB_M)_{(S)} = K_{EQ}$

SOLUBILITY PRODUCT

$(A)^N(B)^M = K_{SP}$

CALCIUM CARBONATE

$CaCO_3(s) \rightleftharpoons Ca^{++} + CO_3 =$

$(Ca^{++})(CO_3^{=}) = K_{SP} = 8.7 \times 10^{-9}$

MAGNESIUM HYDROXIDE

$Mg(OH)_2 \rightleftharpoons Mg^{++} + 2(OH^-)$

$(Mg)(OH^-)^2 = K_{SP} = 1.2 \times 10^{-11}$

CARBON DIOXIDE SYSTEM

$$H_2O + CO_2 \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3 =$$

$$\frac{[H^+][HCO_3^-]}{[H_2CO_3]} = K_1 = 4.47 \times 10^{-7}$$

$$\frac{[H^+][CO_3^-]}{[HCO_3^-]} = K_2 = 4.68 \times 10^{-11}$$

LIME ANALYSIS

Analysis of Lime

The most widely used test for determining available lime is the Rapid Sugar test, which is specified by two important national organizations, the American Water Works Ass'n. and the American Society for Testing and Materials :

AWWA Standard for Quicklime and Hydrated Lime (B 202-65)
ASTM Chemical Analysis of Lime (C 25-67)

Rapid Sugar Test. Dissolve 0.5 gram of—#100 mesh sample of lime in 170 ml. of a 10 per cent sugar solution, shake, and let stand for 30 to 60 minutes. Then titrate with 0.1782N HCl solution, using phenolphthalein indicator. 1 ml. of this standard acid solution is equivalent to 1% available CaO.

The author and other Ohio communities use a modification of the Rapid Sugar test in which N/10 sulfuric acid is used in place of HCl. In this test the burette reading, after titration, multiplied by 2.244 =per cent CaO.

Complete Chemical Analysis. The methods of the American Society for Testing and Materials. (C 25) are recommended.

Slaking Rate Test. The slaking rate of quicklime is a measure of its reactivity, which is determined by a test method included in AWWA B202-65 (adapted from ASTM C110). The quicklime is slaked in a vacuum reaction vessel fitted with a mechanical stirrer and thermometer, and the temperature rise is recorded at 30- and 60-second intervals. The results are reported as temperature rise in 3 minutes, total temperature rise, and total active slaking time.

Specifications for Lime

Either quicklime or hydrated lime of high calcium content can be used for water treatment. Specifications for quicklime usually call for 90 per cent available CaO and for hydrated lime, 68 per cent available CaO. Complete specifications for lime for water treatment can be found in ASTM C 53 and AWWA B 202-65.

SODA ASH ANALYSIS

Analysis of Soda Ash

Dissolve 2 grams of sample in 200 ml. cold, recently boiled distilled water. Titrate 50 ml. with N/2 sulfuric acid, using methyl orange as indicator. Burette reading multiplied by 5.3 = per cent Na_2CO_3.

Specification for Soda Ash

The soda ash shall be that known as 58 per cent soda ash, and shall contain not less than 98 per cent sodium carbonate. The material shall be in a dry powdered form, shall contain no large lumps or large crystals, and shall be free from chips and other foreign matter.

OPTIMAL OPERATION

A. CHEMICAL DOSAGE
   1. FOR GIVEN QUALITY OF WATER
      A) MAGNESIUM REMOVAL
      B) NONCARBONATE HARDNESS
   2. SPLIT TREATMENT
      A) FOR FINISHED WATER QUALITY
      B) FOR MINIMUM CHEMICAL COST
   3. SINGLE STAGE
      A) FOR FINISHED WATER QUALITY
      B) MINIMUM HARDNESS
      C) NONCARBONATE HARDNESS

B. OPERATION
   1. PROPER SOLIDS CONCENTRATION
      A) FINISHED WATER QUALITY
      B) FOR BEST OPERATION
   2. TURBINE OR FLOCCULATOR SPEED
      A) PROPER SOLIDS CONCENTRATION
      B) VARYING WATER QUALITY

SOFTENING SLUDGE CHARACTERISTICS

PRIMARILY $CaCO_3$ AND $Mg(OH)_2$

DRY SOLIDS ARE 85-95% $CaCO_3$

SETTLED SOLIDS RANGE 2 TO 15%

SOLIDS PRODUCTION AVERAGES 2.6 LB/LB OF LIME APPLIED

$CaCO_3$ DEWATERS VARY RAPIDLY, HOWEVER, AS THE % OF $Mg(OH)_2$ INCREASES, DEWATERING BECOMES MORE DIFFICULT.

SOLIDS DISPOSAL

STORAGE PRIOR TO PROCESSING

- SEDIMENTATION BASINS
- SEPARATE HOLDING TANKS
- FLOCCULATOR-CLARIFIER BASINS

THICKENING PRIOR TO DEWATERING

- GRAVITY SETTLING

CHEMICAL CONDITIONING PRIOR TO DEWATERING

- POLYMER APPLICATION

MECHANICAL DEWATERING

- CENTRIFUGATION
- PRESSURE FILTRATION
- VACUUM FILTRATION

AIR DRYING

- SHALLOW LAGOONS
- SAND DRYING BEDS

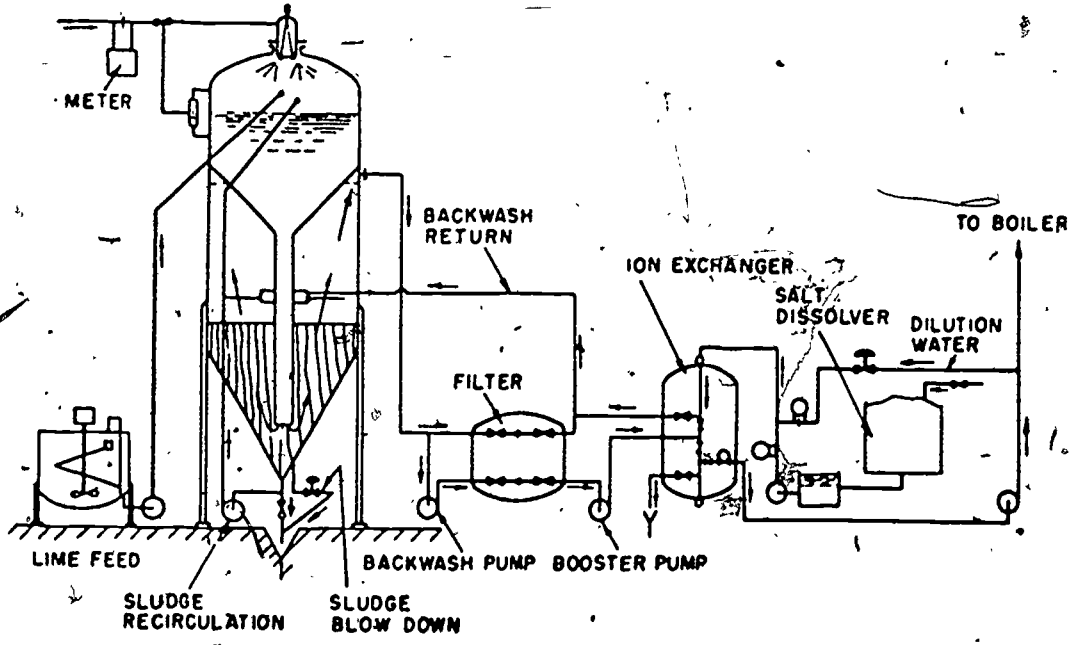
DISPOSAL OF DEWATERED SOLIDS

- SANITARY LANDFILL
- BARGING TO SEA

CHEMICAL RECOVERY

- RECALCINATION OF LIME PRECIPITATES

HOT LIME SOFTENER



TRANSPARENCY MASTERS - #13

CLASS PROBLEMS

for

Training Module II4AGWS

CLASS PROBLEM #1

1. At a pH of 7, what is the dominant form of alkalinity in a natural water? What are the percentages of the other forms of alkalinity.

2. At what pH will the magnesium hardness be below 10 mg/l?

3. If the carbonate concentration is 40 mg/l, what will the calcium concentration be?

4. If the bicarbonate concentration is 200 mg/l and the pH is 7.0, what will be the carbon dioxide concentration?

CLASS HANDOUT

for

Training Module II4AGWS

Handout for II4AGWS - Advanced Chemical Precipitation Softening

I. Introduction
   A. Operation of Two Stage Softening Plant
   B. Operation of Split Treatment Softening Plant
   C. Operation of Single Stage Softening Plant
   D. Laboratory Control for Chemical Softening Plant

II. Theory of Chemical Precipitation Softening
   A. Equilibrium Equation

$$AnBm \rightleftharpoons n\,A^{+} + m\,B$$

Equilibrium Expression

$$(A)^n\,(B)^m/(AnBm) = Keq$$

   B. Solubility Product

$$AnBm \rightleftharpoons n\,A^{+} + m\,B$$

Equilibrium Expression

$$(A)^n\,(B)^m/(AnBm)_{(s)} = Keq$$

Solubility Product

$$(A)^n\,(B)^m = K_{sp}$$

Calcium Carbonate

$$CaCO_3(s) \rightleftharpoons Ca^{++} + CO_3^{=}$$

$$[Ca^{++}]\,[CO_3^{=}] = Ksp = 8.7 \times 10^{-9}$$

Magnesium Hydroxide

$$Mg(OH)_2 \rightleftharpoons Mg^{++} + 2(OH^{-})$$

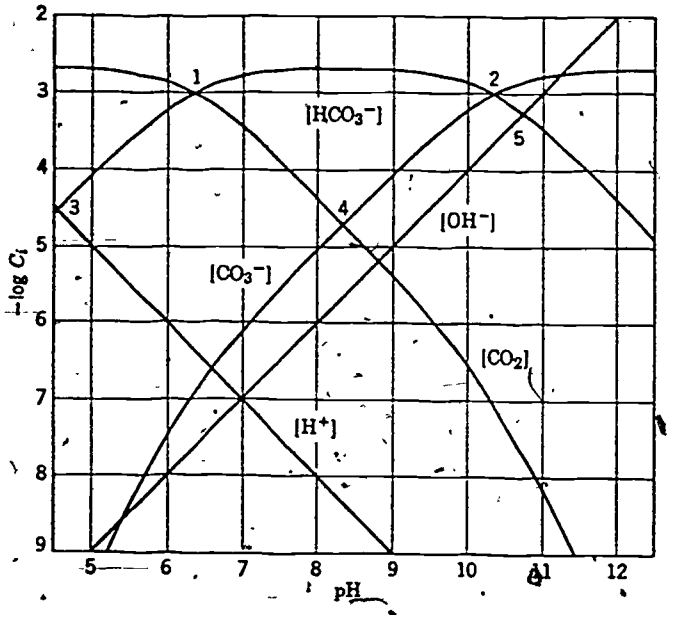
$$[Mg]\,[OH^{-}]^2 = Ksp = 1.2 \times 10^{-11}$$

C. Carbon Dioxide System:

$$H_2O + CO_2 \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^=$$

$$\frac{[H^+][HCO_3^-]}{[H_2CO_3]} = K_1 = 4.47 \times 10^{-7}$$

$$\frac{[H^+][CO_3^=]}{[HCO_3^-]} = K_2 = 4.68 \times 10^{-11}$$



III. Interpretation and Application of Laboratory Data

A. Lime Analysis

The most widely used test for determining available lime is the Rapid Sugar test, which is specified by two important national organizations, The American Water Works Ass'n. and the American Society for Testing and Materials:

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Complete Chemical Analysis. The methods of the American Society for Testing and Materials (C 25) are recommended.

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Specifications for Lime

Either quicklime or hydrated lime of high calcium content can be used for water treatment. Specifications for quicklime usually call for 90 per cent available CaO and for hydrated lime, 68 percent available CaO. Complete specifications for lime for water treatment can be found in ASTM C 53 and AWWA B 202-65.

B. Soda Ash Analysis

Dissolve 2 grams of sample in 200 ml. cold, recently boiled distilled water. Titrate 50 ml. with N/2 sulfuric acid, using methyl orange as indicator. Burette reading multiplied by 5.3 = per cent Na_2CO_3.

Specifications for Soda Ash

The soda ash shall be that known as 58 per cent soda ash, and shall contain not less than 98 per cent sodium carbonate. The material shall be in a dry powdered form, shall contain no large lumps or large crystals, and shall be free from chips and other foreign matter.

C. Optimal Operation
   1. Chemical Dosage
      a. For Given Quality of Water
      b. Split Treatment
      c. Single Stage
   2. Operation
      a. Proper solids concentration
      b. Turbine or flocculator speed

IV. Sludge Disposal
   A. Storage prior to processing
      1. Sedimentation basins
         Separate holding tanks
         Flocculator-clarifier basins
      Thickening prior to dewatering
         Gravity settling
      Chemical conditioning prior to dewatering
         Polymer application
      Mechanical dewatering
         Centrifugation
         Pressure filtration
         Vacuum filtration
      Air drying
         Shallow lagoons
         Sand drying beds

- Disposal of dewatered solids
  - Sanitary landfill
  - Barging to sea
- Chemical recovery
  - Recalcination of lime precipitates

V. Special Applications
   A. Hot Lime

EXAMINATION

for

Training Module II4AGWS

Examination for 114AGWS - Advanced Chemical Precipitation Softening

1. For the following water, what will be the lime and soda dosages to soften the water using the Caldwell-Lawrence Diagram. Assume a final hardness of 50 mg/l as $CaCO_3$.

   CO_2 = 8.8 mg/l Alk = 115 mg/l as $CaCO_3$

   Ca^{++} = 70 mg/l pH = 7.4

   Mg^{++} = 9.7 mg/l

2. For problem #1 what will be the final water quality?

3. For problem #1 what pH should a single stage softener operate at.

4. For problem #1 what will be the final saturation pH.

5. For problem #1 what pH should the water go into the distribution system at.

6. If lime costs $34.00/ton, soda ash $5.00/100 lb. and carbon dioxide $3.25/lb., what will be the cost to treat 1 million gallons of water in problem #1.

TRUE OR FALSE. CIRCLE THE CORRECT ANSWER

T or F 7. A pH of 10.5 is adequate to precipitate magnesium in chemical softening.

T or F 8. For all water qualities, single stage softening will produce the same quality of water as two stage softening.

T or F 9. Solubility product is the base for chemical precipitation softening.

T or F 10. Calcium carbonate precipitates when the solubility product for calcium carbonate is violated.

T or F 11. The advantage of the "Spiractor" is that it produces a sludge that dewaters rapidly.

T or F 12. Softening sludge that contains a low percentage of magnesium hydroxide is more difficult to dewater than one with a higher percentage of magnesium hydroxide.

T or F 13. Hot lime softening results in a lower hardness than cold lime softening.

T or F 14. The most common method of dewatering lime sludge is centrifuges.

T or F 15. The most widely used test for determining available sodium carbonate is the Rapid Sugar test.

T or F 16. Commercial lime is normally 98% available CaO.